Proceedings of the Seminar for Arabian Studies 49 (2019): 51–67

Production and provenance of Gulf wares unearthed in the Old Doha Rescue Excavations Project

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Summary
In this paper, a science-based study of ceramic wares discovered in the Old Doha Rescue Excavations (ODRE) is presented. The ODRE project, run by Qatar Museums and UCL Qatar, discovered a stratigraphic sequence running from the earliest occupation of Doha in the early nineteenth century until the most recent archaeological levels. A strategic selection of ceramic wares from this sequence was studied to shed light on the technological background and provenance of the pottery utilized in Doha between the late nineteenth and the mid-twentieth century. The petrographic study of these wares has provided insight into their mineralogical and petrological composition and their textural characteristics. The textural elements have been used to understand the technology of production of the ceramics, which come from different places around the Gulf. The identification of components has moved us a step closer to the location of places of production by matching compositions and geological backgrounds. The study of glazes with hhXRF, SEM-EDS, and optical microscopy has given us further insight on technological processes in the application of glaze. Finally, a comparison between the macroscopic and microscopic analyses carried out has been produced to shed some light on the inherent difficulties associated with the identification of wares in Gulf ceramics.

Keywords: Islamic archaeology, archaeological science, Qatar, Gulf archaeology, ceramics

Introduction

In this paper, the preliminary results of a science-based study of ceramics retrieved in the Old Doha Rescue Excavations (ODRE) in Qatar are presented. ODRE is a project developed in tandem by Qatar Museums and UCL Qatar which was designed to explore the urban archaeology of Doha, to characterize the material culture of the town over the nineteenth to mid-twentieth century, and to identify changes therein. All these data are being related to historical sources and anthropological accounts of life in the old town. The objectives of the present study of ceramics are to test the classification of wares, developed during the macroscopic and typological study of the pottery retrieved during the project, and to gain initial data on the provenance of the common varieties of late Islamic ceramics.

The ceramics analysed in this study were found in the excavations undertaken by the ODRE team in the centre of Doha. The location of the excavations was determined by the needs of development projects in the city, and the area of work was therefore chosen because it had been selected to be a metro station by Qatar Rail. The pottery was recovered from the layers of a clear stratigraphic sequence: a series of superimposed houses, occupation debris, courtyard deposits, and alley fills found in about 2 m of stratified remains in several trenches in the historic core of Doha. Coin data and other indicators show that the vast majority of the ceramics date from the very late nineteenth century (1890s) to the 1950s. The poorly preserved bottom of the sequence indicates earlier phases of disturbed occupation going back to the beginning of the nineteenth century, in accordance with historical records. Many of the wares identified in these excavations go back to this period and earlier. It is assumed that these ceramics were produced outside Doha, possibly outside Qatar itself, in different areas of the Gulf. In consequence, the main aim of this study is the characterization of a number of selected key wares to allow for future comparisons with other assemblages and, if enough research is conducted in the future, with materials from excavated kilns or from studies of potential clay resources.

Ware Name	Ware and Form Description	References	Dating and other comments
JW: Julfar Ware	Red-brown, brown or grey fabric with frequent sub-angular grits, and whitish inclusions. Quite coarse but can be thin-walled. Generally appears hand-made but sometimes signs of turning on slow wheel. Red-brown or grey slip often visible. Red-brown or purplish paint which is sometimes hard to distinguish against fabric and slip of similar colour. Rare whitish slip (JULFAR.1, more common in earlier centuries). Outside Ras al-Khaimah it usually occurs as cooking pots and multi-purpose globular jars, also barrel-shaped vessels, more rarely small bowls, spouted pouring jars.	Kennet 2004: 70–76. Power 2015: 7–10. Stocks 1996. Mitsuishi et al. 2013.	Twelfth to mid-twentieth century. Kennet divides into four subclasses (JULFAR.1-JULFAR.4) according to surface treatment and fabric colour. Cooking pot rims are chronologically indicative. Manufactured in and around, Wādī Ḥaqīl, Ras al-Khaimah.
RGGW: Red/Grey Gritty Ware	Red-brown, brown or grey fabric with frequent sub-angular grits, and whitish inclusions. Often uneven colouring around large vessels. Similar to Julfar but thick-walled and very gritty. Dark slip sometimes visible. Signs of slow wheel turning at rim. Used for storage jars, often with incised decoration and impressed cordons around the body, sometimes small handles.	Carter 2011: 34, fig. 8 (Coarse Gritty Ware). Costa 1991: 107, 113–114, 139, 151–152, 212–214. Lancaster & Lancaster 2010: figs 17–22, 32–33, 59, 97, 122. Petersen & Grey 2012: 287 (Reduced Coarse Ware and Oxidized Coarse Ware).	Eighteenth to mid-twentieth century, likely earlier origins. Similar to PGGW and PGW but grittier, darker, more variable in colour. Designation originally intended as a catch-all category for related gritty fabrics which are hard to separate into clear wares, though some examples are so similar to Julfar they could be arguably described as Julfar Ware storage jars. Some forms resemble products different kiln sites in Musandam, however.
PGW: Pale Gritty Ware	Brown or buff with moderate or frequent sub-angular dark grits, also rarer whitish inclusions. Appears to be wheel-turned, at least at the rim. Brown, dark brown or reddish slip, which is sometimes absent in areas. Used for storage jars, sometimes with cordons or impressed cordons around the body; also for basins. A slightly finer version (with finer and smaller grits) used for small spouted jars with handle, also medium-sized water jars with handles and no spout.	Carter 2011: 36, fig. 1:1–4, fig. 4: 1–4; fig. 7. Carter & Naranjo-Santana 2011: 49–52.	Nineteenth to mid-twentieth century. Some variability in colour and frequency of grits, especially on large storage jars, and therefore sometimes hard to separate from RGGW and PGGW.
PGGW: Purplish-Grey Gritty Ware	Coarse but dense and hard-fired fabric with moderate or frequent sub-angular grits, and whitish inclusions. Usually dark grey or purplish, sometimes with reddish or purplish core. Storage jars and bowls. Signs of wheel-turning.	ODRE	Can resemble Late Sasanian/Early Islamic gritty wares (Kennet's LISV and Clinky). Denser and more highly fired than RGGW, but often hard to separate and not clearly a separate category.
SW: Sandy Ware	Abrasive-feeling fabric with frequent medium-to-coarse quartz sand, usually with whitish speckles and inclusions. Cream, reddish or buff, often reddish/orange core with cream surfaces. Used for medium-sized jars with pointed bases, large handle fragments (from same jars?), also lids.	Carter 2011: 36, fig. 3: 1–2.	Seventeenth (?) to twentieth century. Note that a very similar sandy ware exists in the Early Islamic period, and perhaps intervening centuries (e.g. the example illustrated in Carter 2011 fig. 3: 1 may actually be Early Islamic). Some macroscopic overlap and shared forms with coarse examples of A'ali Ware. Not identifiable in Kennet's 2004 typology.
FBW: Fine Brown Ware	Fine brown fabric with fine speckling. Comb-incised decoration on shoulder and body. Used for small jars with handle(s), sometimes spouted.	Carter 2011: 33, fig. 2: 1–2. Petersen et al. 2016: 342.	Twentieth century. Cf. Grey's 'Brown Silty Ware' (in Petersen et al 2016). Same as 'Brown A'ali' in Carter (2011: 33) but that name should be discarded.
BW: Bahla Ware	Thin speckled glaze, usually brown or olive, sometimes green or dark brown. Fine reddish fabric with grey areas, usually with fine speckling. Generally bowls with footed or ring bases, occasional small jars, also wider dishes before the nineteenth century.	Kennet 2004: 54–55. Power 2015: 10, figs 7–8. Priestman 2005: 269–270.	Fifteenth to twentieth century. Formerly sometimes referred to as 'Khunj' ware, a designation which should be discarded. Power's Al-Ain sequence indicates that Bahla was still common in the early-to-mid twentieth century, though it was rare outside Oman and the UAE during and after the nineteenth century.

Ware Name	Ware and Form Description	References	Dating and other comments
AW: A'ali Ware	Fine cream or buff fabric, sometimes tending to orange or red-brown. Close examination reveals moderate or rare quartz sand and whitish or rusty inclusions. Comb-incised decoration. Distinctive forms, usually small water jars with three handles; also lids and occasionally small bowls.	Garlake 1978: 166. Carter 2011: 33. Petersen & Grey 2012: 287.	Eighteenth to mid-twentieth century, perhaps starting earlier. Not clearly identified by Kennet, but likely to correspond to BUFF (2004: 81).
MUPW: Manganese Underglaze Painted Turquoise Glazed Ware	Soft cream fabric, fine but often porous and grainy. Thin, speckled turquoise glaze, sometime with panels of darker turquoise glaze, glaze often flaked off, over black paint with geometrical and rosette motifs. Used for bowls with footed or ring bases.	Kennet 2004: 51–52, MGPAINT.2. Priestman 2005: 261–262, MGP.2. Power 2015: 11–12, fig. 7, MANGA.	Seventeenth to twentieth century for this variety.
PFN: Pale Fine Ware	Fine pale brown or buff fabric, sometimes with signs of a brown slip. Small water jars with handle(s) and sometimes spout.	ODRE	Resembles small jars in Pale Gritty Ware, but grits not visible.
FCW: Fine Cream Ware	Fine, whitish or cream ware, no visible inclusions but sometimes fine pores. Sometimes with rouletted decoration or surface-treatment. Used for small, tall water jars, sometimes with handles, and rarely spouted.	Carter 2011: 34–35, fig. 2: 3–8 (Cream Ware).	Probably Iraqi.
TGCW: Thick Grainy Cream Ware	Used for basins and medium-sized wide-mouthed water jars, the latter sometimes with rouletted surface-treatment.	Carter 2011: 34–35, fig. 4: 5–6, fig. 6 (Cream Ware).	Divided from (Fine) Cream Ware in an attempt to distinguish a slightly coarser version used for larger vessels. Can resemble A'ali Ware.

Figure 1. *Names of the wares used in this paper, with relevant descriptions and references.*

The initial study of the ceramics was undertaken by a joint team from Qatar Museums and UCL Qatar, who produced the macroscopic classification of wares[1] that is being used in this paper (ODRE classification).[2] Of all the studied ceramics, 148 samples of twelve different wares were selected and thin-sectioned at UCL Qatar facilities. The study of the samples was undertaken with polarizing microscopes LEICA DM750P and LEICA DM2500P in transmitted plain polarized (PPL) and cross-polarized light (XPL) at the UCL Qatar Archaeological Material Science Laboratories. Of the analysed samples, nine were refired at 1050°C to test the effects of firing atmospheres and temperatures in the petrographic groups related to these samples.[3] In addition, all glazed samples, Bahla and Manganese Underglaze Painted Turquoise Glazed Wares (MUPW), were initially analysed qualitatively using an Olympus Innov-X Delta Premium hand-held X-ray fluorescence (hhXRF) instrument with a 4W, 40kV Rh anode X-ray tube (using a 3 mm collimated beam). On the basis of these results and macroscopic features, sixteen samples of Bahla and MUPW (eight of each, all of them analysed with petrography, except for four MUPW, which were selected only for this study due to the good preservation of their glaze) were prepared at the UCL Qatar laboratories as polished sections and analysed using optical and stereo microscopy and a scanning electron microscope (SEM JEOL JSM-6610LV) with attached energy dispersive spectrometer (EDS Oxford Instruments X-Max^N 50).[4] The EDS analyses were undertaken using the Oxford instruments Aztec

[1] In this study, and following a long tradition of pottery studies, we use the term 'ware' to refer to the groups of pottery determined by macroscopic analysis of the ceramics and 'fabrics' to refer to the groups created by petrographic analysis. The option of denominating 'pastes' to classes of ceramics is used in chemical analysis, because in chemistry the composition of the pottery is considered as a homogeneous compound, unlike in petrography, where the texture of the ceramics composition is key to the analysis.

[2] This team included RC, FAN, FS, and AB from this paper's authors, as well as the work of Francesca Pisano (QM) and Huda Abu Amer and Tracey Cian (UCL Qatar students), whom we thank for their excellent contributions.

[3] MaG prepared the thin sections and refired the selected samples under the supervision of JCL and MyG. The petrographic analysis was done by JCL and MaG.

[4] The study of the glazes was undertaken by EA (UCL Qatar student) under the supervision of MyG, which resulted in a successful MSc dissertation — Adeyemo 2017, in which all the details of this study are presented.

software and calibrations and a cobalt metal standard was measured periodically to monitor and adjust the beam current (for further details on instrument set-up see Živković et al., in press). Finally, forty-nine samples of the 148 were selected for chemical analysis with wavelength dispersive X-ray fluorescence (WDXRF), a work still in progress at the time this article was written. This paper, therefore, presents results based on the information obtained in all the processes described above, except for the chemical elemental analyses, which are still being processed.

Wares and fabrics

Of all the wares identified macroscopically in the ceramics study of the ODRE team, twelve were selected to be analysed in this study. These wares were selected in collaboration with the ODRE team for being the most abundant and the most relevant of the ceramics produced in the Gulf region and found in Doha in the period under study (nineteenth and twentieth centuries). These wares are listed in Figure 1, along with relevant references. Some of them are categories of wares well-known all over the Gulf. In Qatar, they were first identified in an initial classification made by Robert Carter with the ceramics of the Qatar National Museum (Carter 2011) and are now part of the ODRE classification.

The petrographic study was carried out following the method developed by I. Whitbread (1995: 365–396; cf. Quinn 2013). A total of eleven fabrics were identified (Figs 2 and 3), and each fabric corresponds more or less

SN	Wares	Fabrics	SN	Wares	Fabrics	SN	Wares	Fabrics
OD/01	AW	Fabric 5	OD/52	RGGW	Fabric 2	OD/103	BW	Fabric 7
OD/02	AW	Fabric 8	OD/53	RGGW	Fabric 3	OD/104	BW	Fabric 7
OD/03	AW	Fabric 8	OD/54	RGGW	Fabric 4	OD/105	BW	Fabric 7
OD/04	AW	Fabric 8	OD/55	RGGW	Fabric 2	OD/106	BW	Fabric 7
OD/05	AW	Fabric 8	OD/56	RGGW	Fabric 4	OD/107	BW	Fabric 7
OD/06	AW	Fabric 8	OD/57	RGGW	Fabric 3	OD/108	BW	Fabric 7
OD/07	AW	Fabric 8	OD/58	JW	Fabric 1	OD/109	BW	Fabric 7
OD/08	AW	Fabric 6	OD/59	JW	Fabric 1	OD/110	BW	Fabric 7
OD/09	AW	Fabric 5	OD/60	JW	Fabric 1	OD/111	BW	Fabric 7
OD/10	AW	Fabric 8	OD/61	JW	Fabric 1	OD/112	BW	Fabric 7
OD/11	AW	Fabric 8	OD/62	JW	Fabric 1	OD/113	BW	Fabric 7
OD/12	AW	Fabric 8	OD/63	JW	Fabric 1	OD/114	BW	Fabric 7
OD/13	AW	Fabric 9	OD/64	JW	Fabric 1	OD/115	MUPW	Fabric 9
OD/14	AW	Fabric 8	OD/65	JW	Fabric 1	OD/116	MUPW	Fabric 9
OD/15	AW	Na	OD/66	JW	Fabric 1	OD/117	MUPW	Fabric 9
OD/16	AW	LONER	OD/67	JW	Fabric 1	OD/118	MUPW	Fabric 9
OD/17	AW	Fabric 8	OD/68	JW	Fabric 1	OD/119	MUPW	Fabric 9
OD/18	AW	Fabric 5	OD/69	JW	Fabric 1	OD/120	MUPW	Fabric 9
OD/19	PGW	Fabric 3	OD/70	PGGW	Fabric 4	OD/121	MUPW	Fabric 9
OD/20	PGW	Fabric 3	OD/71	PGGW	Fabric 4	OD/122	MUPW	Fabric 9
OD/21	PGW	Fabric 3	OD/72	PGGW	Fabric 1	OD/123	MUPW	Fabric 9
OD/22	PGW	Fabric 3	OD/73	PGGW	Fabric 4	OD/124	MUPW	Fabric 9
OD/23	PGW	Fabric 4	OD/74	PGGW	Fabric 4	OD/125	MUPW	LONER
OD/24	PGW	Fabric 3	OD/75	PGGW	Fabric 4	OD/126	MUPW	Fabric 9
OD/25	PGW	Na	OD/76	PGGW	Fabric 4	OD/127	MUPW	Fabric 9
OD/26	PGW	Fabric 2	OD/77	PGGW	Fabric 4	OD/128	MUPW	Fabric 9
OD/27	PGW	Fabric 2	OD/78	PGGW	Fabric 1	OD/129	FCW	Na
OD/28	PGW	Fabric 3	OD/79	PGGW	Fabric 4	OD/130	FCW	Na

SN	Wares	Fabrics	SN	Wares	Fabrics	SN	Wares	Fabrics
OD/29	PGW	Fabric 2	OD/80	PGGW	Fabric 4	OD/131	FCW	Na
OD/30	PGW	Fabric 2	OD/81	PGGW	Fabric 4	OD/132	FCW	Na
OD/31	PGW	Fabric 3	OD/82	PGGW	Fabric 4	OD/133	FCW	Na
OD/32	PGW	Fabric 2	OD/83	SW	Fabric 5	OD/134	FCW	Na
OD/33	PGW	Fabric 3	OD/84	SW	Fabric 5	OD/135	FCW	Na
OD/34	PGW	Fabric 2	OD/85	SW	Fabric 5	OD/136	FCW	Na
OD/35	PGW	Fabric 3	OD/86	SW	Fabric 5	OD/137	FCW	Na
OD/36	PGW	Fabric 3	OD/87	SW	Fabric 5	OD/138	FCW	Na
OD/37	FPW	Na	OD/88	SW	Fabric 5	OD/139	TGCW	Fabric 8
OD/38	FPW	Fabric 2	OD/89	SW	Fabric 5	OD/140	TGCW	Na
OD/39	PGW	Fabric 3	OD/90	SW	Fabric 5	OD/141	TGCW	Na
OD/40	PGW	Fabric 3	OD/91	SW	Fabric 5	OD/142	TGCW	Na
OD/41	PGW	Fabric 3	OD/92	SW	Fabric 5	OD/143	TGCW	Na
OD/42	PGW	Fabric 3	OD/93	FBW	Fabric 6	OD/144	TGCW	Na
OD/43	FBW	Fabric 6	OD/94	FBW	Fabric 6	OD/145	TGCW	Na
OD/44	FPW	Na	OD/95	FBW	Fabric 6	OD/146	TGCW	Na
OD/45	RGGW	Fabric 2	OD/96	FBW	Fabric 6	OD/147	TGCW	Na
OD/46	RGGW	Fabric 2	OD/97	FBW	Fabric 6	OD/148	TGCW	Fabric 8
OD/47	RGGW	Fabric 2	OD/98	FBW	LONER	OD/149	MUPW	Ns
OD/48	RGGW	Fabric 1	OD/99	FBW	Fabric 6	OD/150	MUPW	Ns
OD/49	RGGW	Fabric 4	OD/100	FBW	Fabric 6	OD/151	MUPW	Ns
OD/50	RGGW	Fabric 1	OD/101	FBW	Fabric 6	OD/152	MUPW	Ns
OD/51	RGGW	Fabric 2	OD/102	FBW	Fabric 6			

Figure 2. *Equivalence of samples, wares, and fabrics considered in this paper. See Figure 1 for acronyms of ware types. Na = Non-assigned (members of FCW or TGCW); Ns = Not studied (four members of MUPW that were considered only in the analysis of glazes).*

Fabric		Ware		Number of misses (TNSF-NM)	Number of errors (TNSW-NM)
Fabric identification	TNSF	Ware identification	NM of TNSW		
Fabric 1	16	JW	12 of 12	4	0
Fabric 2	13	RGGW	6 of 13	7	7
Fabric 3	16	PGW	14 of 22	2	8
Fabric 4	15	PGGW	11 of 13	4	2
Fabric 5	13	SW	10 of 10	3	0
Fabric 6	11	FBW	10 of 11	1	1
Fabric 7	12	BW	12 of 12	0	0
Fabric 8	13	AW	11 of 18	2	7
Fabric 9	14	MUPW*	13 of 14	1	1

Figure 3. *A list of fabrics and wares together with a comparison between the sample numbers of the identified fabrics and the sample numbers of the identified wares, with misses (macroscopic identifications that fail to recognize the fabric, e.g. two of the sherds identified as Fabric 3, which is typical of PGW, had been classified as other kinds of ware) and errors (macroscopic identifications that take other fabrics for the fabric in question, e.g. eight sherds which had been classified as PGW turned out to have fabrics other than Fabric 3, which was the fabric most typical of PGW). See Figure 1 for acronyms of ware types. * The MUPW group includes only the samples that have been thin-sectioned.*

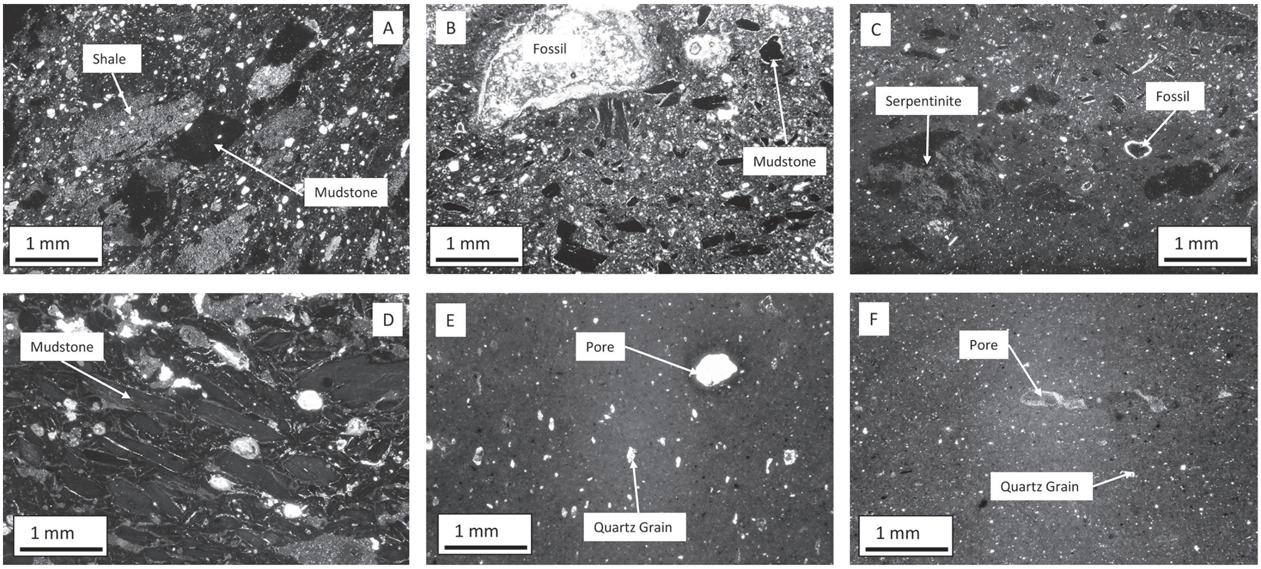

Figure 4. *Petrographic microphotographs:* **A.** *Fabric 1;* **B.** *Fabric 2;* **C.** *Fabric 3;* **D.** *Fabric 4.* **E.** *an example of the fabric of Thin Cream ware;* **F.** *an example of the Thick Grainy Cream Ware;* **A and C–D.** *images taken in cross polarized light (XPL);* **B and E–F.** *images taken in plane polarized light (PPL).*

accurately to one of the wares (although not always exactly, as explained below). The only exception is Pale Fine Ware, which was spread in between different fabrics and consequently its constitution as a ware is not supported by petrographic analysis (see discussion of this point below). After the petrographic study, the fabrics (and their correspondent wares) can be divided into three groups that are defined texturally: the Gritty Group (see Fig. 4/A–D), which contains abundant inclusions of mudstones and shales (the grits); the Quartzitic Group (see Fig. 5), defined by the abundant presence of microcrystalline quartz; and the Fine Calcareous Group (see Fig. 4/E–F), which contains extremely fine fabrics. The last group is composed of Fine Cream Ware and the Thick Grainy Cream Ware and will not be discussed in this text because the petrographic analysis has not provided any useful information due to the extreme fine nature of the fabrics that compose it; support of the chemical elemental analysis will be required here. There are three outsiders that do not fit within the classification, samples with fabrics that do not match any of the groups formed by petrographic analyses and cannot be defined until further research is undertaken. Consequently, the rest of the paper will focus on the fabrics and wares contained in the Gritty Group and the Quartzitic Group.

In the Gritty Group, we can highlight the presence of Fabric 1 (corresponding to Julfar Ware), defined by a large number of inclusions (20–40%), which are dominated by shales and mudstone. The rest of the members of the group — Fabric 2 (Red/Grey Gritty Ware), Fabric 3 (Pale Gritty Ware), and Fabric 4 (Purplish Grey Gritty Ware) — are defined by other characteristics, such as the higher or lower presence of calcareous and/or serpentinitic rocks and calcite and quartz in the matrix. The Quartzitic Group includes on the one hand Fabrics 5 and 8 (Sandy and A'ali Wares respectively), both with rounded quartzitic sand grains and on the other, three fabrics defined by different contents of angular and subangular monocrystalline quartz, ophiolitic rocks, and calcareous mudstones: Fabric 6 (Fine Brown Ware), Fabric 7 (Bahla Ware), and Fabric 9 (MUPW) (see Fig. 6).

Technology

Petrography and the techniques of glaze analysis contemplated in this paper offer useful insights to initiate reconstructions of segments of the *chaîne opératoire* of production of the different fabrics, although any statement is subject to experimental testing (something that this study cannot offer). With

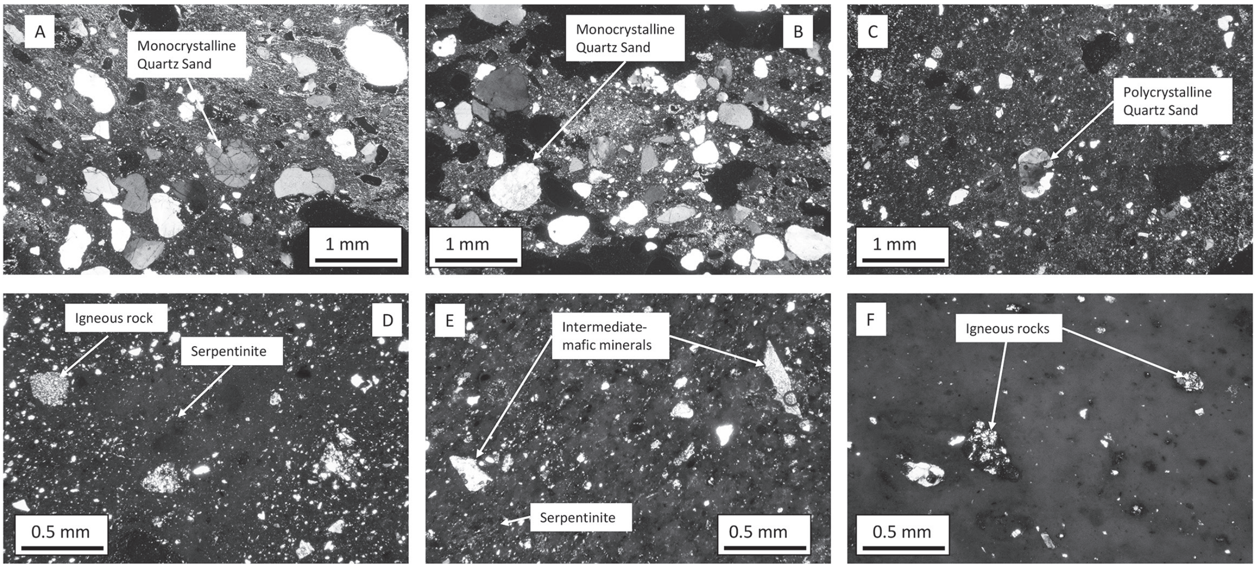

Figure 5. *Petrographic microphotographs:* **A–B.** *Fabric 5;* **C.** *Fabric 8;* **D.** *Fabric 6;* **E.** *Fabric 7;* **F.** *Fabric 9. All images were taken in XPL.*

Fabric number and name	**Textural characteristics**	**Main inclusions**	**Technological implications**
Fabric 1: Coarse fabric tempered with shale and mudstone	Few pores (1–15%), abundant inclusions (20–40%) with weak alignment and bimodal grain-size distribution. Few or no optical activity.	Shale (Predominant to Frequent, largest of 4.25 mm; mode = 1 mm); Mudstone (Predominant to Few, largest of 3.2 mm; mode = 1 mm). Others in coarse fraction include limestone, greywacke, serpentinite and igneous rocks.	Raw materials from sedimentary environment with incipient metamorphism and detritic minerals. Tempering is very likely, clay mixing and levigation are possible. High firing temperature, oxidizing atmosphere in kiln. Similar technology to Fabrics 2, 3 and 4.
Fabric 2: Coarse calcareous fabric tempered with mudstone and shale	Few pores (5–10%) and inclusions (5–15%) with weak to strong alignment and bimodal grain-size distribution. Calcareous matrix. Few or no optical activity.	Mudstone (Predominant to Few, largest of 4.25 mm, mode = 1.5 mm). Others in coarse fraction include shale, limestone, calci-mudstone, serpentinite and igneous rocks.	Raw materials from sedimentary environment with incipient metamorphism and detritic minerals. Tempering is very likely, clay mixing and levigation are possible. High firing temperature, oxidizing atmosphere in kiln. Similar technology to Fabrics 1, 3 and 4
Fabric 3: Calcareous fabric with serpentinite	Few pores (1–15%), moderate inclusions (5–20%) with weak to strong alignment, bimodal grain-size distribution. Calcareous matrix, no optical activity	Serpentinite (Dominant to Few, largest of 4 mm, mode = 1 mm); Limestone and fossiliferous limestone (Dominant to Few, largest of 3.25 mm, mode = 0.25 mm). Others in coarse fraction include mudstone, amorphous concentration features and igneous rocks.	Raw materials from sedimentary environment with notable presence of serpentinites. Tempering is very likely, clay mixing and levigation are possible. High firing temperature, oxidizing atmosphere in kiln. Similar technology to Fabrics 1, 2 and 4.
Fabric 4: Argillaceous mudstone fabric	Moderate pores (3–20%) and abundant inclusions (3–40%) with weak alignment, bimodal grain-size distribution. No optical activity	Amorphous concentration features (Predominant-Dominant; largest of 4.4 mm, mode = 1.5 mm). Others in coarse fraction include limestone, shale, serpentinite and igneous rocks.	Raw materials from sedimentary environment. Tempering and levigation are very likely, clay mixing is possible. High firing temperature, oxidizing atmosphere in kiln. Similar technology to Fabrics 1, 2 and 3.

Fabric number and name	Textural characteristics	Main inclusions	Technological implications
Fabric 5: Fabric with coarse rounded monocrystalline quartz	Few pores (3–10%), abundant inclusions (15–40%) without alignment and with unimodal grain-size distribution. Some optical activity.	Monocrystalline quartz (Predominant, largest of 1 mm, mode = 0.75 mm). Others in coarse fraction include crystalline and aplastic concentration features, micritic limestone, feldspar, polycrystalline quartz, serpentinite.	Sand tempering. Otherwise, the characteristics are very varied and could be a fabric composed of the output of different workshops.
Fabric 6: Fine ophiolitic fabric	Few pores (0–7%) and moderate inclusions (5–17%), aligned and unimodal grain-size distribution. Some optical activity.	Igneous rock (Dominant; largest of 1.1 mm, mode = 0.2 mm); Monocrystalline quartz (Dominant; largest of 0.3 mm, mode = 0.2 mm). Others in coarse fraction include polycrystalline quartz, feldspar, serpentinite, micritic limestone, crystalline and amorphous concentration features and detritic minerals	Raw materials from ophiolitic environment. Levigation is very likely. Moderate firing temperature in oxidizing atmosphere. Very similar to Fabric 7.
Fabric 7: Fine calcareous ophiolitic glazed fabric	Few pores (0–5%) and moderate inclusions (5–18%) with weak alignment and unimodal grain-size distribution. Calcareous matrix, no optical activity.	Crystalline concentration features (Dominant; largest of 1.1 mm, mode = 0.2 mm). Others in coarse fraction include detritic minerals, feldspar, micritic limestone, serpentinite and igneous rocks.	Raw materials from ophiolitic environment. Levigation and clay mixing are very likely. Moderate firing temperature in oxidizing atmosphere. Very similar to Fabric 6
Fabric 8: Fine fabric with rounded crystalline quartz	Moderate pores (1–20%) and inclusions (7–20%), aligned and with bimodal grain-size distribution. No optical activity.	Monocrystalline quartz (Predominant; largest of 1.5 mm, mode = 0.25 mm). Others in coarse fraction include crystalline concentration features, igneous rocks, feldspar, micritic limestone and serpentinite.	Raw materials from a sedimentary environment with presence of limestones and igneous rocks. Tempering is possible. High firing temperature and oxidizing atmosphere.
Fabric 9: Fine glazed fabric with rounded crystalline quartz	Few pores (1–5%) and moderate inclusions (7–20%), aligned and with unimodal grain-size distribution. No optical activity.	Monocrystalline quartz (Predominant; largest of 0.85 mm, mode = 0.25 mm). Others in coarse fraction include crystalline concentration features, igneous rocks (rhyolitic and basaltic), feldspar, micritic limestone, serpentinite and detritic minerals.	Raw materials from a sedimentary environment where ophiolites are present. High firing temperature and oxidizing atmosphere.

Figure 6. *Names and descriptions of the fabrics considered in this paper (see Whitbread 1995: 365–396 for a full description of the system used).*

petrography it is possible to assess the procedures and circumstances surrounding the preparation of clay recipes of each fabric, including the characterization of raw materials, the combinations of different clays (levigated or with their natural inclusions), and potential tempers used by the potters;[5] and the process

[5] In petrographic and chemical ceramic analysis, the term 'temper' is reserved for those inclusions that have been added deliberately by the potter, and it is therefore distinct from the inclusions that are found as natural components of the clays used.

of firing, including insights on the temperature and atmosphere of the kiln (Whitbread 2001). The study of glazes with optical microscopy and SEM-EDS techniques illuminates their composition, which can in turn be used to understand their recipes and application procedures (Molera et al. 2001).

The fabrics of the Gritty Group are characterized by the frequent appearance of shales and mudstones that could be the result of either clay mixing, with the shales and mudstones being a natural part of a primary clay containing those elements, or deliberate tempering, with the aim of controlling the plasticity of the recipe. The heterogeneous textures of the fabrics of this group, and particularly those of Fabric 2 (Red/Grey Gritty Ware) and Fabric 4 (Purplish Grey Gritty Ware), suggest that their recipes contained different amounts of distinct clays. Heterogeneous distributions of micrite (microcrystalline calcite) also suggest recipes that were obtained through the mixture of different clays (which can also be naturally heterogeneous). In the cases of Fabric 2 (Red/Grey Gritty Ware) and Fabric 3 (Pale Gritty Ware) at least one of these clays is calcareous, although these concentrations of calcite can be the result of secondary calcite in some cases (Cau Ontiveros, Day & Montana 2002). If clay mixing and tempering are considered, then some of the basic clays may have been levigated to form the base of the recipes. Once the clay recipe was completed, the vessels were modelled by hand or on a wheel, though not a very fast one, as the alignment of inclusions and voids to the margins is only rough. They would be fired at generally high temperatures (900–1000°C), enough to eliminate most of the optical activity of the matrix, but within variable ranges of specific temperatures and atmospheres.

Generalizations are a bit more difficult in the case of the Quartzitic Group. Fabric 5 (corresponding to Sandy Ware) is a possible case of tempering with sand and a modelling process on a slow-rotating wheel. Apart from those two characteristics, the clay matrix where the quartz is incrusted varies widely in the different samples of the fabric. One can suggest that rather than being the output of a single workshop, this fabric is composed of samples from different workshops. Fabric 8 (A'ali Ware) is more homogeneous and characterized by the presence of quartzitic aeolian sand and calcareous mudstones which may be there as temper. The existing workshops in the village of ʿĀlī make use of levigation,[6] and it is certainly a possibility in the case of the archaeological samples of Doha, which have a fine texture if we leave aside the inclusions (although the samples taken from wasters of the present production are even finer; see Fig. 10). Fabric 8 was modelled on a wheel and fired to a high temperature with a relatively homogeneous oxidizing atmosphere. The three remaining wares of the Quartzitic Group — Fabric 6 (Fine Brown Ware), Fabric 7 (Bahla Ware), and Fabric 9 (MUPW) — share many characteristics: fine fabrics, probably the result of levigation; recipes obtained possibly by mixing of clays, in particular in Fabric 7; modelling on the wheel, with relatively high speed of rotation; and firing to high temperatures with diverse atmosphere ranges.

The glaze analysis performed by Elizabeth Adeyemo on Bahla Wares (Adeyemo 2017) showed that, in spite of their macroscopic homogeneity, there is a wide variability in their composition, although in general they can be identified as lead-barium silica types, to which iron oxide (FeO) could have been added as a colourant. This type of glaze is quite exceptional as it has only been documented before in China under the Eastern Han Dynasty, and yet the glazing technique used seems to be different as well. The Chinese wares were made by the application of a frit containing lead and barium. In the Bahla glazes, however, the wide variation in the correlation between barium and lead in the glaze composition of each sample suggests that the combination of the two elements was naturally found in the minerals used to add lead, rather than being the result of a deliberate recipe (in which the proportions of lead and barium in the glaze would probably have been stable) (see Fig. 7/A). The analysis therefore suggests that the glazing technique used with the Bahla glazes consisted of the application of a solution with lead-/barium-containing minerals and silica grains in suspension over the leather-hard vessels (see Fig. 7/B–D), rather than the use of a frit, as was the case with the Chinese glazes (cf. Živković et al., in press).

The analysis of the glazes of the MUPW show different compositions and a different application technique. The turquoise glazes contain no lead and relatively high concentrations of potassium and sodium oxides (K_2O

[6] JCL and RC were able to see several levigation pools in action during a visit to ʿĀlī in 2016.

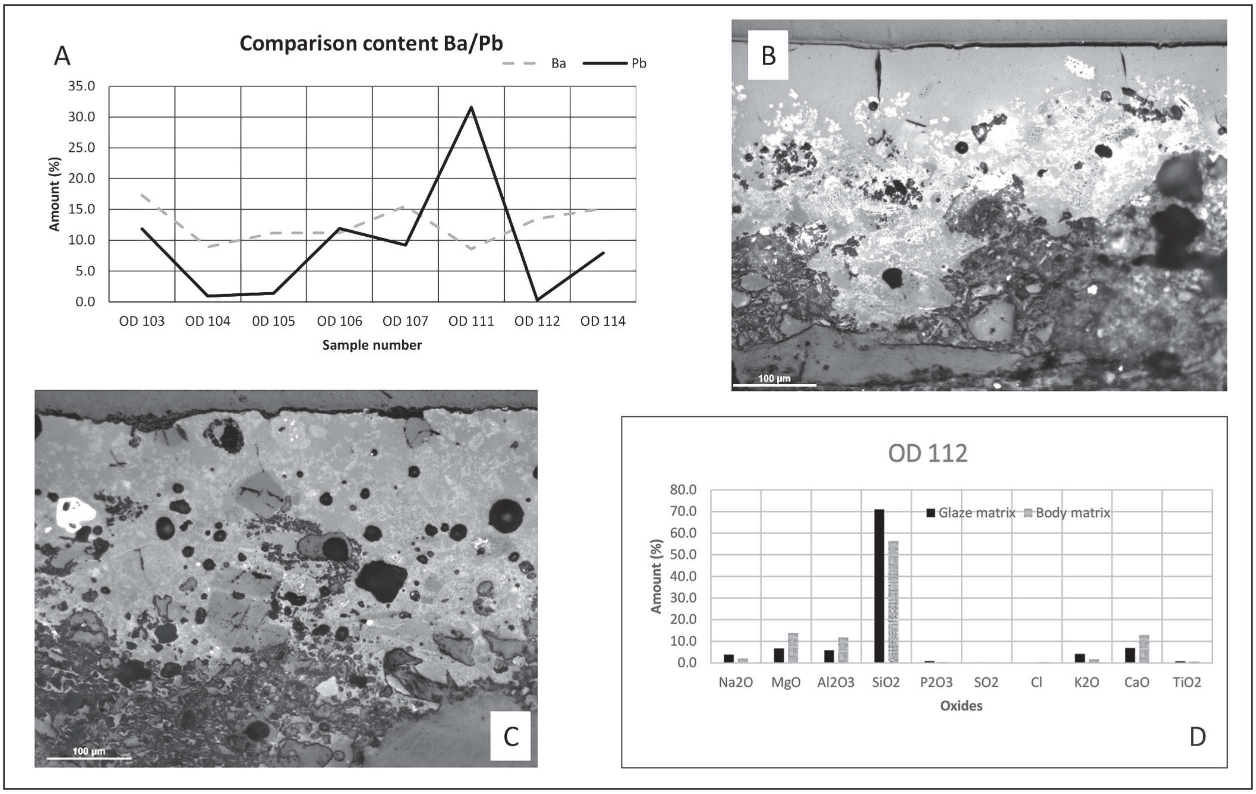

Figure 7. *Images produced during the analysis of Bahla glazes (see Adeyemo 2017):* **A.** *a comparison of the amounts of lead (Pb) and barium (Ba) in different samples;* **B.** *an image of sample 105 and* **C.** *an image of sample 106 showing high interface interaction (suggesting that the vessel was not fired before the application of the glaze) and high content in sand, bubbles, and other materials. The images were taken by reflected light optical microscopy (OM) in XPL, and their scales indicate 100 µm;* **D.** *a comparison of the normalized compositions (after removing iron, lead, and barium) of glaze and ceramic paste in sample 112, showing higher contents in silica (SiO2) in the glaze than in the matrix, suggesting that silica (sand) was added to the solution of lead/barium minerals applied for the glaze.*

and Na_2O respectively in Fig. 8/A), which means that they are alkali-based, made with plant ash, and applied as frits mixed in a suspension with silica grains over the leather-hard ceramics (Fig. 8/B). Their turquoise colour was most likely due to diffusion of iron in the glaze from the ceramic matrix and the manipulation of copper in the glaze recipe through the addition of either copper oxide or molten fragments of metal alloys (as the presence of tin oxides in some samples suggests). The decoration technique of this ware consists of the application of manganese oxide (Fig. 8/C) under the glaze, as correctly described in the name of the ware (Adeyemo 2017).

Provenance

A study of the provenance of the fabrics considered in this paper can be approached with a combination of the data obtained in this study along with available geological, archaeological, and ethnographic evidence. It must be remembered, however, that at present this approach can only be considered limited and very constrained: only one assemblage in a particular period of time is being considered and there are no parallel studies on petrography that can offer terms of comparison for Gulf ceramics in this period, with the exception of the study by Živković et al. (in press).[7] For

[7] The main petrographic work done in the Gulf by Blackman, Méry and

A — GLAZE CONTENT

Sample	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_3	SO_2	Cl	K_2O	CaO	TiO_2	MnO	FeO	CuO	BaO
115	8.2	2.1	3.2	70.0	0.1	0.1	0.5	6.7	5.3	0.2	0.3	1.1	0.6	
119	6.9	2.6	3.7	68.5	0.2	0.1	0.6	8.2	5.8	0.2	0.5	1.1	0.7	0.1
122	7.0	2.9	3.6	71.1	0.2	0.0	0.6	8.6	6.3	0.2		1.2		
125	5.7	1.8	3.3	68.5	0.2	0.1	0.6	9.2	5.8	0.2		0.9	0.4	
149	6.2	3.0	4.2	68.5	0.0	0.1	0.3	8.9	5.9	0.2	0.8	0.9	0.5	0.2
150	6.4	2.0	4.5	67.7	0.2	0.1	0.7	9.3	5.4	0.3	0.1	1.0	1.4	
151	7.4	2.3	3.9	67.5	0.3	0.1	0.3	5.6	5.9	0.3	0.8	1.4	0.2	
152	7.9	3.3	2.7	68.7	0.1	0.0	0.6	7.1	6.3	0.1	1.2	0.8	0.2	0.2
Total	7.0	2.5	3.6	68.8	0.2	0.1	0.5	8.0	5.8	0.2	0.6	1.1	0.6	0.2

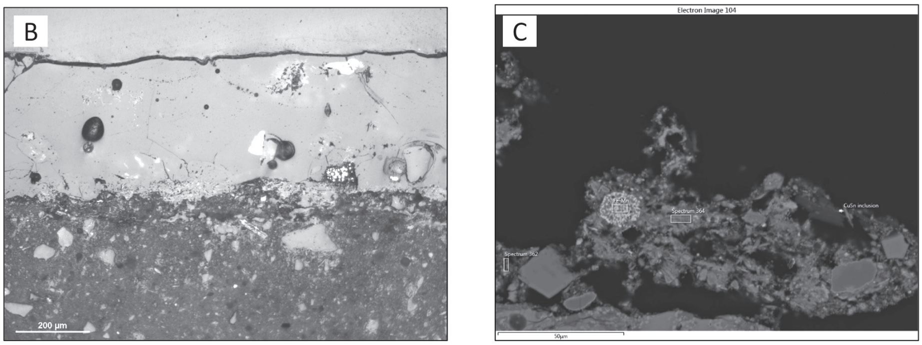

Figure 8. *Images produced during the analysis of MUPW glazes (see Adeyemo 2017):* **A.** *composition (wt%) of glazes of all samples analysed, showing a high content in sodium (Na2O) and potassium oxide (K2O);* **B.** *OM (XPL) image of glaze in sample 119, showing sand inclusions and bubbles (scale = 200 µm);* **C.** *back-scattered electron (BSE) image of underglaze paint in sample 125, composed mainly of manganese oxide (scale = 50 µm).*

this reason, this paper will be limited to some views on the regional provenance of the wares discussed. A more extensive and nuanced knowledge of wares in the future will allow us to pinpoint more specific places of production.

Julfar ware (Fabric 1) is possibly the best studied ware of this assemblage in Gulf archaeology. Mitsuishi et al. (2013) established the precise location of the kilns where this ware was being produced in the period of Doha's expansion (nineteenth and twentieth centuries). William and Fidelity Lancaster (2010) described the process of manufacture of the pottery as explained by the Banū Shamāylī of Wādī Ḥaqīl, which is consistent, in principle, with observations about the technology based on petrography:

> 'Potters used *three or four different sorts of clay from different places*, mixed in varying proportions depending on what items they intended to make, with a major division between pots as containers and cooking pots. Muhammad bin Qaysi said that as a very rough division, hard clays were used for containers but not for cooking pots as they cracked when they came into contact with the heat of the fire. Soft clays were used for cooking pots. Rashid bin Haimur described *three clays, red, green and yellow*. Red clays were abundant,

Wright (1989) and S. Méry on Omani ceramics (1991; 1995; 2000), is focused on prehistoric material and on regions of the Oman peninsula dominated by a geology different than the one we need to consider here, but it offers interesting parallels for this research which have not been considered in this work due to time constraints. The authors were excited to hear Méry's presentation on the ceramics of Umm al-Quwain, presented at the Seminar for Arabian Studies in 2018, which introduced materials made in regions much closer to those of our interest, and are looking forward to that publication. Petrography was also one of the methods considered by Mynors (1983) and Stremtan et al. (2012), all focused on prehistoric material.

found on the surface or between rocks and sand and the most used. Green clay was scarce and mingled with earth and mountain rocks, and could be difficult to dig out. It was mixed, at the workplace, with red clays and a little yellow. The yellow clays tended to be very pale to almost white, and were found among rocks in the mountains. This clay was mixed with other clays to make it stronger and to harden and improve it, so it did not break so easily in the heat of the kiln. White clays from Iran were sometimes brought in, but these did not stand up to firing properly' (Lancaster & Lancaster 2010: 230; present authors' emphasis).

The main petrological types of inclusions observed in Fabric 1 are shales and mudstones, precisely the characteristic geological components of the Shargi (Sharqī) Member (easternmost) of the Fiqa Formation that can be found in the limit with the Hajar mountains of Oman (Alsharhan 1995) (see Fig. 9). Given that all the fabrics of the Gritty Group are similar in terms of technology and components, we can use the precise location of the kilns of Julfār, the technological knowledge documented by the Lancasters in different places of the Musandam peninsula, and the particular geology of this area to propose possible locations for the rest of the fabrics. The processes of pottery production described by the Lancasters are generic enough to correspond to any of the fabrics under discussion (2010: 208–255). However, the geological background of the regions where the pottery production areas as identified by the Lancasters are located is very different to that of Julfār, because the production areas are located not in the Fiqa Formation, but in the Ḥajar Group — richer in carbonate rocks — and in other formations (the Hawasim [Ḥawāsim] and Haybi [Ḥaybī] Units and the Semail [Samāʾil] Ophiolite), where a larger content of ophiolitic

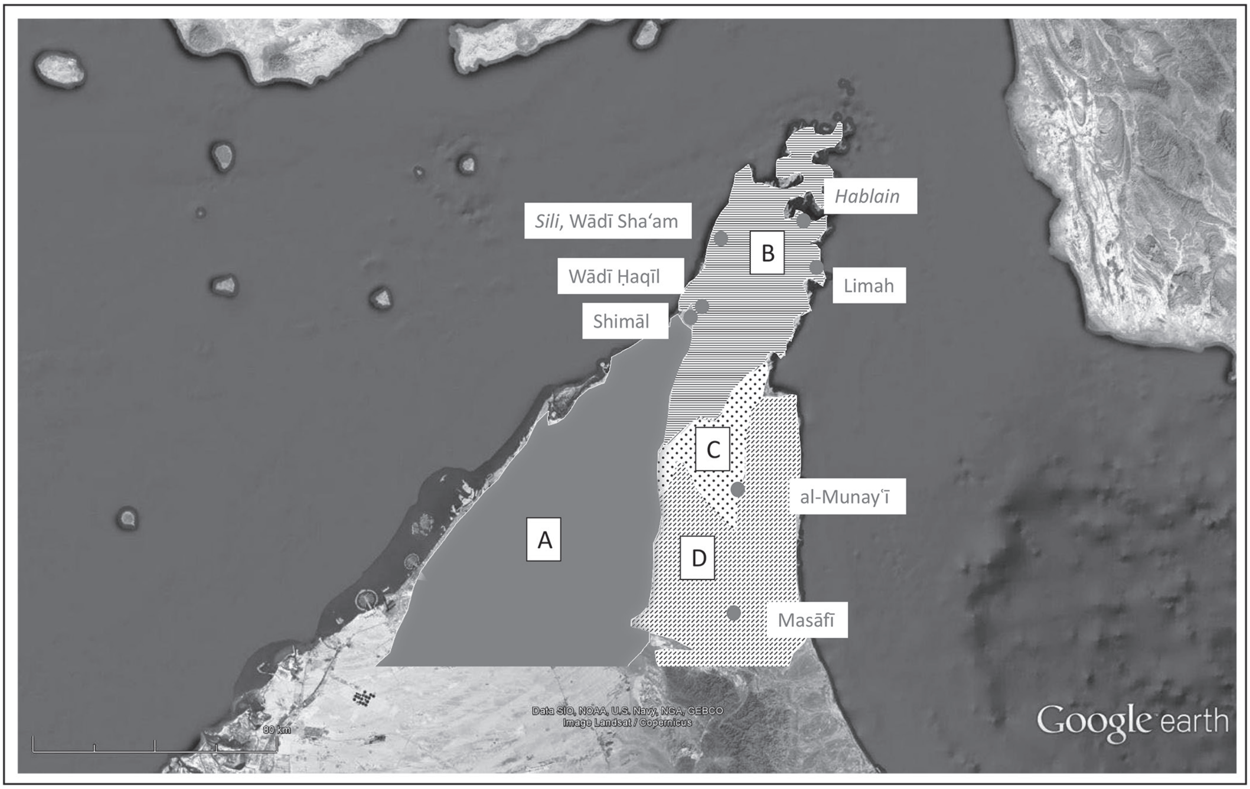

Figure 9. *A map of Musandam showing the pottery production sites (as indicated in Lancaster & Lancaster 2010: 208–255; base map from Google Earth, scale = 80 km; the geological areas are crudely marked following maps in Alsharhan 1995: 49; Alsharhan & Nairn 2003: 60):* **A.** *Fiqa Formation;* **B.** *Ḥajar Group;* **C.** *Hawasin (Ḥawāsin) and Haybi (Ḥaybī) Units;* **D.** *Semail (Samāʾil) Ophiolite.*

rocks would be expected. The particular mixture of possible ophiolites with the shales and mudstones of Fabric 3 (consistent with Pale Gritty Ware) could, in principle, be compatible with the geological locations in the south and interior of the Musandam peninsula — for example Masāfī and al-Munayʿī — but the other two Gritty Wares are more compatible with environments related to the Fiqa Formation and to the Ḥajar Group, in other words, locations in the northern coastal areas of Musandam (Arsharhan & Nairn 2003: 59–62) (see Fig. 9).

The provenance of the fabrics of the Quartzitic Group is less straightforward. The most widespread and well-known of the fabrics of this group is Fabric 7 (Bahla Ware), for which there have been discussions to determine its provenance. The two hypotheses that have been considered most likely are the towns of Khunj in Iran and the town of Bahlāʾ in Oman (Kennet 2004: 54). Fabric 7, found in Doha, seems to be quite homogeneous in petrographic terms. The composition of the clay and the sands observed in the glaze shows abundant serpentine and mafic and ultramafic igneous rocks, all of it compatible with the geology of the area of Bahlāʾ in the Semail Ophiolite of Oman (Hunting Survey Ltd 1986a; 1986b), but not with that of Khunj in Iran (Spaargaren 1991; cf. Živković et al., in press); thus the location of Bahlāʾ is favoured as the provenance of the wares in this study. It is interesting to note that Fabric 6 (Fine Brown Ware) is so similar to Fabric 7 that in terms of petrography it could be considered an unglazed version of it. It is therefore reasonable to look for the provenance of this fabric in Bahlāʾ itself, or at least in any workshops in a similar geological area and with a similar technological manufacturing process. It has been shown above that the glaze composition and application of Fabric 9 (MUPW) is very different from that of Fabric 7 (Bahla Ware), but it should be noted that Fabric 9 shows a very similar process of production to that observed in Fabrics 6 and 7. The geological background of the raw materials observed in Fabric 9 is also similar to those of Fabrics 6 and 7, but a slightly higher presence of felsic (rhyolitic) rocks than of mafic (basaltic) in its fabric is documented. This is still compatible with the upper layers of the Semail Ophiolitic complex (Arsharhan & Nairn 2003: 59–62), but there are no outcrops of these layers in Bahlāʾ (Hunting Survey Ltd 1986a; 1986b). Instead, the origin of this ware should be looked for in areas near outcrops of the upper layers of the Semail formation in the Oman peninsula or in the outcrops of the Zagros Thrust or the volcanic deposits of Iran (Spaargaren 1991).

Fabric 8 (A'ali Ware) can be linked to Bahrain by the active kilns and numerous deposits of wasters which can still be viewed at A'ali (ʿĀlī), Bahrain. The petrographic analysis of the fabric has been compared to petrographic samples of ten wasters and three clay samples taken from the workshops in the locality of A'ali recently.[8] The petrological composition of Fabric 8 and of the wasters and clay samples is very similar, and this supports the idea that Fabric 8 was indeed made there. It is notable that the texture of the wasters is finer than that of Fabric 8 samples; this could be the result of the introduction of a more refined levigation process or it could just be that potters today are using clays from a different quarry. In fact, potters nowadays claim to have their clay brought to them from another village in the centre of the island, al-Rifāʿ, which was not the case with the oldest potteries (Steffen Terp Laursen, personal communication) (see Fig. 10).

The most difficult fabric to provenance is Fabric 5 (Sandy Ware). Its most visible component is rounded sand, which is obviously very widely spread over the Gulf region. An interesting clue is that the characteristics of the sand inclusions are a high maturity (grains are rounded and well sorted), a relatively large size (some of them almost on the scale of gravel), and a plutonic or metamorphic origin, which are all characteristics easily found in lower Iraq (but not necessarily absent from south Iran or the eastern Arabian plate).

Comparison perceptions of wares and fabrics

It is important to discuss the combination of the macroscopic and microscopic (petrographic) points of view put forward in this paper. Discussion of the combination of scientific analyses with archaeology has been lengthy and is still going on. Many archaeologists

[8] These samples were taken during a trip to A'ali by RC and JCL in 2016. Our thanks are due to Steffen Terp Laursen, director of the Moesgaard Museum expedition in Bahrain, for his support in guiding and helping us to contact potters. The wasters were thin-sectioned by MaG at UCL Qatar laboratories. The clay samples were used to make briquettes that were fired at 600°C, 900°C, and 1050°C and then thin-sectioned by MaG in the same facilities.

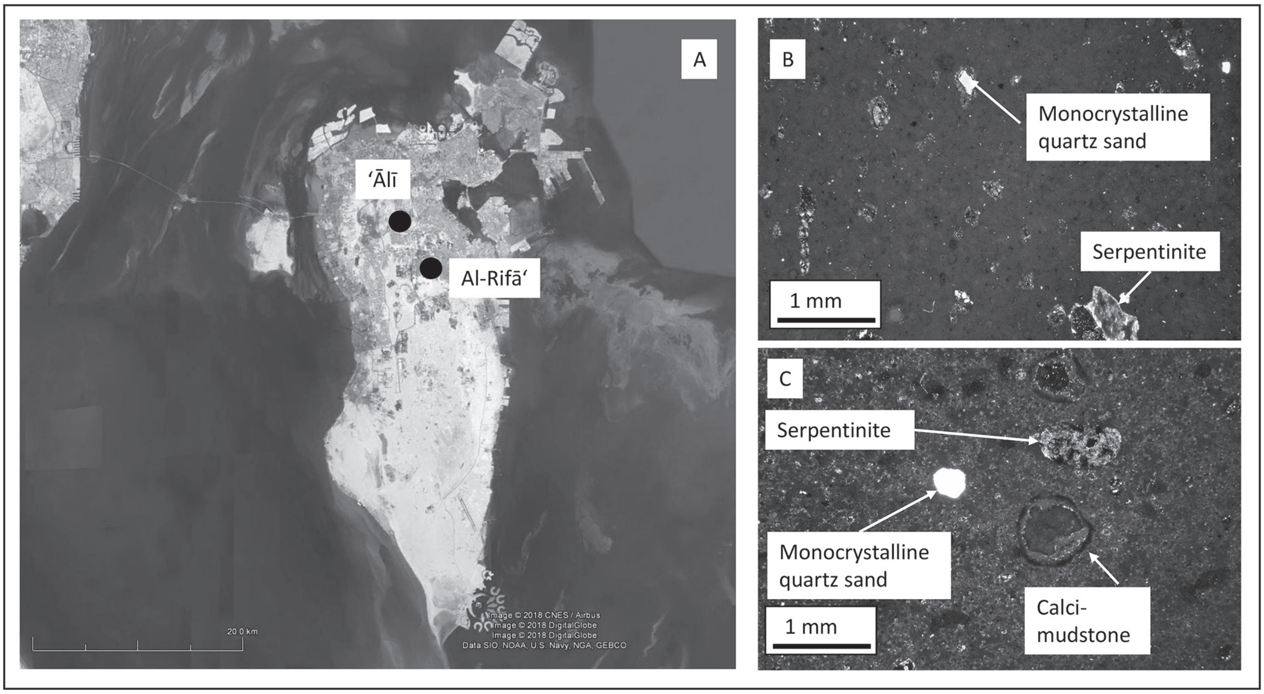

Figure 10. A. *A map of Bahrain showing the location of A'ali (ʿĀlī) and al-Rifāʿ (map from Google Earth, scale = 20 km);* **B.** *a petrographic microphotograph from a clay sample taken from a pottery workshop in A'ali, fired at 1050°C;* **C.** *a petrographic microphotograph of a sample taken from a waster from a workshop in A'ali.*

tend to see in some scientific analyses a very expensive methodology that can be used to test certain interpretations without regard to the many necessary caveats; and many non-archaeologist scientists fail to find ways in which their contribution to archaeological interpretation can be made relevant and adjusted to questions from the archaeologists themselves. This small project can contribute to the debate by providing a small discussion on how petrography and macroscopic ceramic analysis can work together in a way that is constructive from both points of view. Figure 3 offers a comparison of different perceptions of the ceramics under study from the points of view of macroscopic and microscopic analysis, considering the matches (when the macroscopic and the microscopic analysis coincide in their identification), misses (when the macroscopic analysis fails to identify wares with their correspondent fabric), and errors (when the macroscopic analysis identifies wares with a fabric that is not the correspondent one). The divergences are not very notable and can be explained relatively easily, showing that the two interpretations are consistent with the ideas developed in this paper.

The comparison numbers between macroscopic and petrographic interpretations are particularly good (high in matches, low in misses and errors) in the glazed groups and in the Quartzitic Group in general. In this group there are always fewer than three misses and fewer than two errors (except in the case of Fabric 8, A'ali Ware, in which there are seven errors). The most problematic numbers (low on matches, high in misses and errors) are related to the Gritty Group, which has numbers as high as seven misses and eight errors, although overall the figures are better than that. This is caused by the similarity between the wares, which is particularly problematic at the macroscopic level, where core and surface colours, texture, and the appearance of inclusions are the key elements to establish differences between wares. As the wares of the Gritty Group have so closely similar compositional and technological techniques, the inherent variability between colour, texture, and the appearance of inclusions tends to overlap, making it very difficult to distinguish them. The same problems are also apparent in petrography, but the larger range of parameters available to make distinctions makes it easier to establish significant differences between fabrics.

Conclusions

Between its foundation at the beginning of the nineteenth century and the beginnings of the oil economy in the mid-twentieth century, Doha was one of the best-connected cities of the Gulf, as the excavations and macroscopic studies on ceramics undertaken under the ODRE project are showing. In this paper a programme to develop a science-based analysis of different wares identified in the assemblage of Doha has been initiated. The petrographic study of 148 samples has allowed the definition of nine fabric groups that can be correlated to nine wares identified in the macroscopic analysis. With the study of these fabrics it is possible to highlight some of the stages of the production processes used to make these fabrics. Besides this, an identification of the main petrological and mineralogical components of the vessels has been produced, which has led to some useful observations to establish the sources of the raw materials used in the vessels. The analysis of glazes with hhXRF, SEM-EDS, and optical microscopy has offered another set of results which can be used to identify segments of the *chaîne opératoire* of the application of glazes to the vessels, as well as complementary information on the identification and provenance of the raw materials used. This information will be expanded in the future with a more complete analysis of the petrographic fabrics and the inclusion of elemental chemical analyses with WDXRF.

In the last section of the paper, the relationship between the processes of identification of wares and fabrics by macroscopic and microscopic (petrographic) studies respectively has been addressed. This gives a useful perspective on the variable difficulty that there is in identifying any ware correctly by macroscopic means alone. In general, wares of the Quartzitic Group are quite easy to identify, while those of the Gritty Group are a bit more complicated, with the exception of Julfar Ware.

Acknowledgements

The analysis that made this paper possible were funded by UCL Qatar. The authors wish to thank Francesca Pisano for her efforts in the development of the ODRE classification, and Tracey Cian and Huda Abu Amer for their collaboration in sorting out many of the ceramics of the ODRE project. Additionally, thanks are due to Steffen Terp Laursen for his guidance and help in collecting samples from Bahrain.

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